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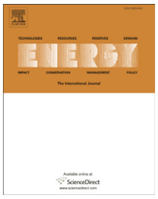

The impact of subsidies and carbon pricing on the wood biomass use for energy in the EU

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ABSTRACT

This study examines how subsidies for wood-fired heat and power plants and wood with coal co-fired power plants influence the use of wood biomass for energy in the short (2020) to medium (2030) term in the EU (European Union). Analysis shows that without subsidies wood-fired electricity will take only a marginal market share due to limited availability of low-cost wood from logging residues. A high CO_2 price of 100 €/t without subsidies results in 30 million m^3 of industrial wood used for energy production, which is sourced from the reduction of 12 million m^3 for wood products, 10 million m^3 additional imports and 8 million m^3 additional harvest. With a subsidy level of 30 €/MWh in the four EU member countries Denmark, Germany, Netherlands and UK, the total amount of industrial wood used for energy becomes 158 million m^3. In the latter case, reduction of wood for wood-based products is 35 million m^3, additional harvest in the EU is 21 million m^3, and import to the EU is 102 million m^3. Subsidies to wood-fired and especially coal with wood co-fired mills substantially increase the use of wood and especially industrial wood for energy. However, even with a high 100 €/tCO_2 price and subsidy, mostly gas-fired electricity is projected to be displaced in 2030 by the increasing use of industrial wood, which is not beneficial regarding reducing the high CO_2 emission from power production using coal. To a large extent, subsidies for wood co-firing maintain the coal power share, which will otherwise be reduced at high carbon emission price level. In addition, the model results show that the main sources of the growing use of industrial wood for energy are imports from regions outside of the EU, which thus creates considerable carbon leakages.

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1. Introduction

The EU (European Union) has set strong targets for reducing the GHG (greenhouse gas) emissions by at least 80% below 1990 levels by 2050 in order to halt the global climatic warming to 2 °C [1]. Before that, the EU had put in place legislation to reduce its emissions to 20% below 1990 levels by 2020. Studies by the ECF (European Climate Foundation) [2] and the EC (European Commission) [3] address the feasibility and implications of the 80% emissions abatement objective. One of the consequences of achieving that objective would be high CO_2 prices after 2030; over100 €/t in 2040 and 200 €/t in 2050.

According to the ECF [2], RES (renewable energy sources) are going to play a key role in achieving EU energy sector decarbonisation targets in 2050 by supplying a major part of electric power and heat. By 2030, RES energy supplies are expected to provide 55–60% of the EU electricity production, while the remainder will be provided by nuclear power, coal and gas. The use of coal and gas is expected to gradually diminish as a result of reduced CO_2 emission allowances sold on the EU ETS (Emissions Trading System) and rising CO_2 prices. Since coal and gas are the two most important fuels used in Europe in power production, their prices and the CO_2 emission prices will affect how the new RES, including wood biomass, will compete for the share of the power market. However, carbon emission prices are very low in the EU at present, and the major drivers of RES supply are various subsidies. According to Badcock and Lenzen [4] subsidies for biomass are the second highest per unit of electricity produced after solar power. Coal with wood co-firing is often seen as a low cost and efficient way of achieving the 20% RES target set by the EU for 2020 [5]. Despite the "low cost" image of coal with wood co-firing it receives hefty subsidies in the UK, the Netherlands and some other EU member states, and the efficiency of such policies are questioned by non-scientific sources [6]. The EU target for reducing GHG emissions by 80% has caused strong debates among different industry groups. The CEPI (Confederation of the European Paper Industries) states in

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its report [7] that with the increasing CO_2 prices, the forest products industries will have to compete for the wood biomass with coal plants, which will find it increasingly cost-effective to substitute wood for coal. Also, the bioenergy producers are highly interested in how much wood biomass will be available and at which prices.

It is therefore of considerable interest to analyse the impacts of increased demand for wood biomass for bioenergy in the EU. These impacts depend rather strongly on the kind of subsidies used. Thus, in this article we examine how various kinds of subsidies for wood-fired heat and power plants and wood with coal co-fired plants influence the use and price of wood biomass for energy in the short (2020) to medium (2030) term in the EU, in competition with the forest industries.

Most of the previous studies deal only with the technical and economic potentials of using wood for energy [8], or look at the wood market implications taking either biomass prices [9] or biomass use [10] as given, or they look at the biomass scenarios without considering their market implications [11]. On the other hand, energy sector-related studies tend to take biomass price and supply as given [12,13]. IAMs (Integrated Assessment Models) such as REMIND, MERGE, POLES and IMAGE-TIMER have been used to assess the biomass use for climate mitigation scenarios [14,15]. However, the wood biomass was mostly limited to the wood energy plantations and logging residues. There is no forest sector as such within the IAM framework, which limits the possibilities for studying interactions between energy and the forest sector. Few studies have looked into the interaction between the energy sector and the forest sector. Lauri et al. [16,17] and Moiseyev et al. [18] provide an exception. In these studies, use of wood for energy is endogenous and the major driver of increased usage of energy wood is different levels of carbon emission prices. In Moiseyev et al. [18] subsidies for energy wood were also considered as an additional driver of increased use of wood for energy, but the main focus was on carbon emission prices.

In Sjølie et al. [19], the Norwegian forest sector model was complemented by a district and household heating model in order to study the impact of various levels of carbon emission prices and investment subsidies on the substitution of fossil fuel by wood fuels. A tax of 60 €/CO_2 on fossil fuels was found to increase use of wood for district heating substantially. However, a 50% subsidy for district heating installation combined with much lower carbon emission tax helped to increase the use of wood for district heating to almost the same levels. Both carbon emission tax and investment subsidy were deemed to be effective policy measures to increase the use of wood biomass for energy.

A similar study [20] for Finland was carried out with the Finnish forest sector model SF-GTM (Finnish Global Trade Model) augmented with a heat and power energy model [21]. In order to reach 20% RES targets for Finland in 2020, a modest carbon emission tax and a small subsidy for wood-based electricity combined with a subsidy for small tree harvesting were assumed. A target of energy wood for 2020 can be reached with the proposed carbon tax and subsidies, but a reduced forest carbon stock due to increased harvesting will result in increased CO_2 emissions leading to an overall negative carbon emission balance within a 2035 time frame.

A model of the Finnish electricity and heat market [22] was used to study feed-in tariffs and a subsidy to renewable energy together with the CO_2 emission price. Subsidising forest biomass combustion in a co-firing power plant decreases the investment in pure renewable technology (wind power). However, the use of fossil fuels (coal and gas) increases modestly when the carbon emission price is set at low levels. The CO_2 intensity of electricity production is nearly equal whether biomass co-combustion is subsidised or not. Since subsidising wood with coal co-fired electricity production results in lower electricity marginal costs, the use of both coal and wood pellets can increase when the CO_2 emission price level is low. This could lead to the so-called Green Paradox, when subsidising biomass causes the increased use of fossil fuels [23].

We will focus on the large-scale power and heat sector in the EU and examine the potential demand for wood fuel by the coal and wood-fired power and heat plants and the question of how this demand depends upon different kinds of subsidies and different developments of the prices of CO_2. We model coal, gas and wood-based power and heat for the existing technologies in the aggregated form (one technology for each fuel type for each country). With such a level of technical details we do not regard this model as a “realistic” full scale energy model. However, it allows us to consider the competition between coal, gas and wood for the energy production taking interaction with the global forest sector into account. Our approach is similar to Moiseyev et al. [18], but in this paper we study different levels of subsidies and varying levels of adoption of wood for energy subsidies among EU member countries. Compared to Lauri et al. [16], the energy sector representation is expanded to cover the gas power sector, and we also take into consideration the wind and solar PV (photovoltaic) power production based on the projections of expected future capacity expansions by ECF [2,24]. For the analysis, we use the same version of the partial equilibrium model for the global forest sector, the EFI-GTM (European Forest Institute Global Trade Model) model, as used in Moiseyev et al. [18]. It covers the whole world, which allows us to fully account for the international trade of wood biomass and forest products. The EFI-GTM model does not take into account more local small-scale electricity and heat production including domestic boilers. However, the main growth in wood biomass use for energy is expected at large-scale industrial facilities [25], where various subsidies are given in order to reach the 20% EU RES target.

2. Methodology and main data assumptions

In the analysis, we use the EFI-GTM global forest sector model [9,26]. In Moiseyev et al. [18], the model was revised to include heat and power produced from coal, gas and wood into the modelled commodities, which previously consisted of the forest and forest industry products only. Four types of thermal power electricity generating plants (by type of fuel used – lignite, coal, gas and wood), four types of heat plants and four types of CHP (combined heat and power) plants were included, as described more in detail in Moiseyev et al. [18].

Electricity and heat production is described as a process with fixed fuel inputs and other non-fuel costs. Coal and gas prices are exogenous, but they can change over time according to the scenario assumptions. Wood used as fuel can be obtained from logging residues and from industrial wood (sawlogs, pulpwood and sawmill residues) converted to energy chips and wood pellets. Electricity and heat generation efficiencies for eight types of thermal power and CHP plants are based on data from the database of the GEMIS (Global Emission Model for Integrated Systems) [27]. Required fuel input corresponds to the electricity efficiency and is also based on GEMIS data. The average estimate for the LHV (low heat value) of hard coal and lignite is taken from Schuster and Peterson [28]. The LHV of wood is based on United States Forest Service – Forest Products Laboratory [29], and is assumed to be 13.76 MMBtu per tonne of air-dried wood (20% moisture content) and 12.04 MMBtu per tonne of semi-dried wood (30% moisture content). The average weight of wood is assumed to be 0.6 tonne/m^3 (air dry wood). Consequently, air-dried wood has an LHV of $13.76 \times 0.6 = 8.26$ MMBtu/m^3 (8.7 GJ/m^3) and semi-dried wood has an LHV of $12.04 \times 0.6 = 7.22$ MMBtu (7.6 GJ/m^3). The LHV of wood pellets is assumed to be 13.6 MMBtu per tonne [29]. For coal with wood pellets, co-firing 20% of energy input is assumed to be coming from pellets. The emission factors are based on the CO_2 content of the fuels and the amounts of the respective fuels needed to produce 1 MWh of heat and/or power (fuel efficiency). Wood-fired plants are assumed to be CO_2 neutral. Investment and production costs for thermal power, wind and solar PV are based on the estimates from ECF [2,24]. For the modelling costs of new electricity generation technologies, we have used the commonly applied LCOE (Levelized Cost of Electricity) method, and specifically the simplified LCOE method as applied in Tarjanne and Kivistö [30].

Our focus is on the question of how wood biomass will compete with coal and natural gas in the future. However, as the development of the supply of solar and wind power is also expected to play a significant role in the EU low carbon economy, we have accounted for solar and wind power exogenously. According to the EC Energy Roadmap 2050 [31], the electricity production is projected to increase from 3400 TWh in 2010 to 4100 TWh in 2030 in the reference scenario. The supply of thermal energy is projected to keep stable over the period of 2010–2030, while in the decarbonisation scenarios, it is projected to decline from 1900–2000 TWh (2010–2015) to 1250–1400 TWh in 2030 due to a sharp increase in wind and solar power generation. Based on that, we assume that the quantity corresponding to the current amount of electricity produced by thermal power, about 1900 TWh, must be supplied by competing gas, coal and biomass fired power plants or, up to a certain extent (about 800 TWh) by solar PV and wind power in the future. The rest of the power supply will come from hydro or nuclear power plants and also from wind and solar power. However, that part of the power supply is exogenous to our analysis. The thermal electricity production is kept at 1900 TWh level, but the supply is subject to competition between coal, natural gas and biomass fired plants. Demand for thermal electricity and heat is assumed to be inelastic.

The capacities of the current coal, gas and biomass fired power, heat and CHP mills in European countries (except the Commonwealth of Independent States) are based on Platts World Electric Power Plants Database [32]. Additional capacity for thermal energy may come on stream depending on the profitability of these investments. The current capacity and potential increases of the regional wind power and solar PV capacity are modelled in accordance with the projections by ECF [2], adjusting the figures for 2050 in the "Higher RES" scenario to the year 2030 [24]. Country-level demand for heat from CHP and district heating and electricity (gross electricity generation is used as a proxy for the demand) is based on the "EU energy trends to 2030" report [33].

The supply of logging residues is constrained to a certain share of industrial wood harvest. These shares used were based on the scenario "Promoting wood energy" in the EFSOS (European Forest Sector Outlook Study) II report [25]. The costs of logging residues at mill gate are based on the report "Environmentally compatible Bioenergy Potential from European Forests" [34], and are typically within the range 25–35 €/m^3, which is in most cases lower than the respective price for pulpwood. For GDP (Gross Domestic Product) growth, we used the assumptions of the IPCC (Intergovernmental Panel on Climate Change) B2 reference scenario with medium economic growth. The other assumptions are as described in Moiseyev et al. [9].

The assumptions on the prices of carbon, coal and natural gas are of particular importance in the analyses. We assume a linear increase in the European coal prices to 85 €/t in 2020 from the present level of 70 €/t, and an increase in natural gas prices from the 8.5 €/MMBtu to 11 €/MMBtu[1] in 2020. These assumptions are in line with or similar to those in ECF [2]. For the CO_2 emission price, four alternative development paths are considered:

1. Present carbon emission price level of 10 €/tCO_2 constant until 2030.
2. Low scenario: 30 €/tCO_2 in 2020 rising linearly to 40 €/tCO_2 in 2030.
3. High scenario: 40 €/tCO_2 in 2020 rising linearly to 100 €/tCO_2 in 2030.
4. Very high scenario: 40 €/tCO_2 in 2020 rising to 140 €/tCO_2 in 2030.

In all four cases, the carbon emission price is assumed to be 10 €/tCO_2 until 2015, and then to rise linearly up to 2020 assumed levels. In addition we assume two levels of subsidies for wood-fired and wood with coal co-fired electricity production in a few EU member countries.

We assume Norway and Switzerland take part in the EU ETS system, while other non-EU regions are not participating. This assumption strongly affects the price of wood in Europe and the competitiveness of the European forest sector relative to other regions.

3. Results and discussion

3.1. *Shares of the electricity production in the EU region under alternative CO_2 prices without subsidies*

Under the scenario with 40 €/tCO_2, coal is a major supplier of electricity (51%), while wood-fired power provides around 5.3% of the total (Fig. 1). A carbon price of 100 €/tCO_2 results in a price of electricity exceeding 120 €/MWh in 2030, which allows solar PV power to enter the electricity market more actively. Coal power share goes down to 8% with gas power almost doubling its share to 40%. A high electricity price also favours wood-fired electricity to a limited extent; its share increases to 6.8%. With a very high 140 €/tCO_2 price, coal power practically disappears, while gas reduces its market share only modestly, and wood-fired power increases marginally up to 7.7% of the EU electricity market share. Hardly any co-firing of wood with coal takes place.

Despite a low share (<7–8%) of wood-fired electricity, wood-based heat is projected to go up to 31% of the total heat provided by the medium- to large-scale energy sector. The use of wood biomass is projected to increase from 151 million m^3 to 256 million m^3 with increasing CO_2 prices. While most of these volumes will come from the lowest-cost logging residues, a

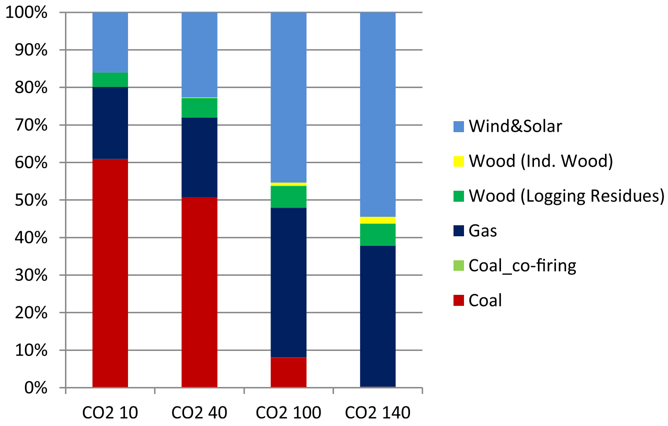

Fig. 1. EU electricity market shares in 2030 with different carbon emission prices (without subsidies).

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[1] MMBtu refers to Million British Thermal Units. 1 Btu = 1055.056 J.

significant share of 32 million m^3 may come from industrial wood sources with the high CO_2 prices of 100 €/tCO_2, and industrial wood supply for energy almost doubles to over 60 million m^3 with CO_2 prices of 140 €/tCO_2.

The main result is that wood-fired electricity is able to gain only a marginal market share due to limited availability of low-cost wood from logging residues. Industrial wood starts to be used increasingly only at high carbon emission prices of 100 €/tCO_2. With carbon emission prices well above 100 €/tCO_2, more wood biomass will become available for energy. While looking at the current situation such carbon prices seem very high, but such prices might occur if the low carbon Europe roadmap becomes a reality [3].

The use of industrial wood for energy could be higher under different forest sector market developments and in the presence of additional policies which stimulate the faster introduction of renewable energy sources. The main instrument for stimulating acceleration of renewable energies in the EU has been feed-in tariffs. In addition, investment subsidies, extra bonuses and renewable obligation certificates are used. In the following section we analyse the role of subsidies.

3.2. *The impact of subsidies for wood-based electricity on the use of wood for energy*

We include subsidy (compensation) for wood-fired electricity produced at power and CHP mills by specifying an additional compensation for the production costs at the level of 30 €/MWh of electricity (which is just a bit higher than the lowest level of “NawaRo” bonus in Germany for power production using solid renewable biomass) [35].

We assume 30 €/MWh and 60 €/MWh as a compensation for co-firing wood and wood pellets with coal. The 30 €/MWh level is nearly 50% lower than the present renewable obligation certificate in the UK of about 55 euros. High-level subsidies are also used for wood with coal co-firing in the Netherlands and Denmark. We assume a 30 €/MWh and 60 €/MWh level of coal co-firing subsidy in the UK, Netherlands, Denmark and Germany from 2015. The 30 €/MWh level of compensation will barely cover annualised capital costs for a new wood-fired power/CHP mill. However, this level of compensation will cover higher wood fuel costs and provide an extra bonus for the existing coal-powered mills. These subsidies will increase the relative competitiveness of wood-fired power mills and especially for co-fired coal and wood energy production. In addition, to see the impacts of Germany, we model one scenario with subsidies of 30 €/MWh as a compensation for co-firing wood and wood pellets with coal in only the UK, Netherlands, and Denmark from 2015.

With the assumed 30 €/MWh subsidy in the four EU member countries (UK, Netherlands, Denmark and Germany) and a carbon price of 40 €/tCO_2 in 2020, the subsidy helps to maintain coal power share to a large extent, while it increases the use of wood for wood-fired mills only moderately (Fig. 2). Including more countries subsidising wood firing and co-firing increases the use of wood for energy more substantially than increasing the level of subsidy. A 60 €/MWh subsidy level in the four EU countries increases wood with coal co-firing only modestly compared to the 30 €/MWh level. Removing Germany from the countries subsidising wood use for energy has a great impact on lowering the volume of wood used with coal co-firing. In the short term (2020), subsidies for wood firing and wood with coal co-firing will have a major impact on increasing coal with wood co-firing, but these subsidies will have a modest impact on the reduced share of gas power and a marginal impact on the increased share of the wood-fired power. However, in 2030 under a 100 €/tCO_2 price level, subsidies for wood co-firing are going to maintain coal power share to a large extent, which will be lost otherwise due to the high carbon emission price level (see Fig. 3). Market share of the coal co-firing power will increase mostly at the cost of the reduced share of the gas power. Subsidies for wood-fired and wood with coal co-fired power will have a negligible impact on wood-fired power. Coal co-firing power mills become the major beneficiaries of these subsidies.

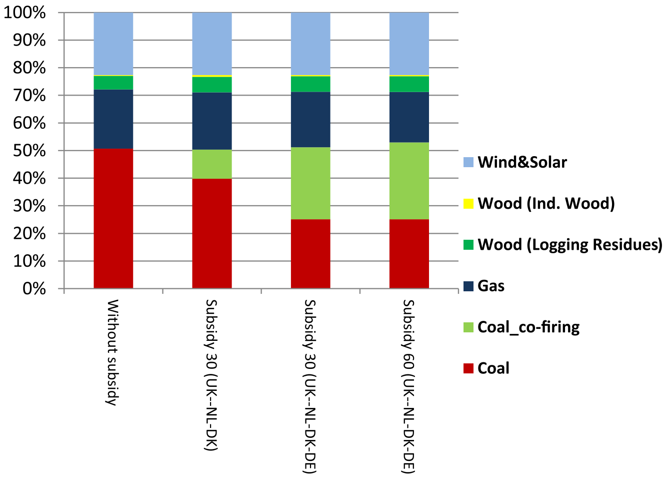

Fig. 2. EU electricity market shares in 2020 under CO_2 price 40 €/ton with and without subsidies.

Subsidies will increase the use of wood for energy in 2030 mainly by increasing the use of industrial wood, while the use of logging residues increases only marginally, since the supply of logging residues is limited by harvest levels. An extra source of industrial wood comes to the energy sector by diverting wood from the wood-based sector, which is hurt by increasing wood prices and especially electricity prices under higher carbon price levels. Additional wood is also increasingly imported from other regions with increasing carbon prices and subsidies.

It is important to note that subsidies for wood-fired and especially coal with wood co-fired mills substantially increase both the use of wood residues and especially industrial wood for energy. Consequently, wood displaces both coal and gas from the electricity markets. In the short term (2020) with low carbon prices (40 €/tCO_2), wood could displace about 10% coal, but it will be partly offset by a reduced market share of gas. However, the European Commission's general strategy is to increase the use of gas and

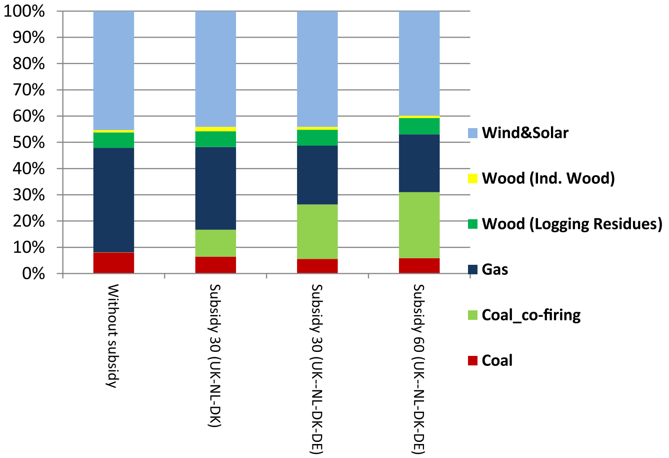

Fig. 3. EU electricity market shares in 2030 under CO_2 price 100 €/ton with and without subsidies.

Table 1
Projected change of the use of industrial wood for energy by source in 2030 relative to the low 10 €/tCO$_2$ scenario, million m^3.

Subsidy for wood energy	Additional industrial wood for energy from				Logging residues	Total logging residues + industrial wood for energy
	Wood products	Imports	Harvest	Total wood		
No subsidy CO$_2$-100	11.5	10.3	8.5	30.2	224.0	254.2
Subsidy 30 UK–NL–DK–DE e/MWh	34.5	101.8	21.5	157.8	230.9	388.7
Subsidy 30 UK–NL–DK e/MWh	27.1	72.7	17.3	117.1	228.3	345.4
EFSOS II	21.9	31.6	16.1	69.6	271.9	341.5

reduce the use of coal in the medium term (until 2030). Our study shows that it will require much higher carbon prices to achieve this. Increased carbon prices and subsidies for wood seem to influence rather strongly the distribution between coal and gas. However, even with a high 100 €/tCO$_2$ price and subsidy, mostly gas-fired electricity is projected to be displaced in 2030 by the increasing use of industrial wood, which is not beneficial regarding reducing the high CO$_2$ emission from power production using coal. In addition, the model results show that the main sources of the growing use of industrial wood for energy are imports from regions outside the EU, which potentially creates considerable carbon leakages, and reduces the self-sufficiency and security of the EU's energy supply.

3.3. *Use of wood for energy and wood-based products*

Table 1 shows the projected increase of wood use for energy and corresponding sources from the reduction of wood-based products, imports and additional harvests under scenarios studied in the previous sections. A high CO$_2$ price of 100 €/t results in an increase of 30.2 million m^3 of industrial wood used for energy production. The 11.5 million m^3 reduction of wood use in the EU forest industries in 2030 corresponds to 2% of the industries' total wood use. The additional 10.3 million m^3 of industrial wood for energy comes from increased imports to the EU, which in 2030 increases from 36.6 million m^3 in the Low price scenario to 46.3 million m^3 in the High price scenario. The remaining 8.5 million m^3 of industrial wood come from additional harvesting (compared to the low carbon price scenario). With a subsidy level of 30 €/MWh in the four EU member countries, the total amount of industrial wood used for energy is over five times more than the amount without subsidy. In the latter case the reduction of wood for wood-based products is three times more than without subsidy, additional harvests are two and a half times higher, and imports are 10 times higher compared to the no-subsidy case. Subsidies for firing wood will mainly hit the pulp and panel industries. With a subsidy level of 30 €/MWh in the three EU member countries, the total amount of industrial wood used for energy is 25% lower compared to a subsidy applied in the four countries, but still four times higher than in the no-subsidy case with a high carbon emission price in 2030. However, the amount of logging residues used for energy is nearly the same in all cases.

The last row of Table 1 shows the figures estimated in the EFSOS II report [25]. The total amount of wood biomass for energy from industrial wood and logging residues compares closely with the EFSOS II report and a subsidy of 30 €/MWh in the three EU member countries case. The distribution between industrial wood and logging residues for energy is different. EFSOS II estimates 44 million m^3 more from logging residues and 47 million m^3 less from industrial wood supply. Both the EFSOS II report and this paper are based on the same high utilisation of logging residues estimates. This paper, however, takes into account production costs for electricity and heat generation and the fact that the production capacities of heat and power do not match with the potential supply of logging residues and chips. This leads to the logging residues potential not being fully utilised. As a result, the remaining wood for energy is supplied from industrial wood supplies, where imports into the EU play a major role.

The model results show that without subsidies, imports of wood to the EU region mainly come from Russia. With the subsidy North America becomes the biggest exporter of wood for energy, which will mainly be traded in the form of wood pellets. Russia and Latin America will be the second and third largest exporters of wood pellets and wood chips for energy.

It can be clearly seen that the harvest level is mainly affected by subsidies for the wood-fired and coal with wood co-fired power, and that increasing the CO$_2$ price has a more substantial effect on increasing industrial wood harvest only in the case of the very high 140 €/tCO$_2$ carbon emission price (Fig. 4). In the latter case, the harvest level is still lower than with subsides applied in the three EU member countries. Increasing carbon prices has a more modest impact on the amount of wood used by EU forest products industries in comparison to the impact of subsidies (Fig. 5). A subsidy of 30 €/MWh for wood firing and co-firing with coal will cause the most dramatic reduction of wood used for forest products. Increasing the CO$_2$ price up to 100 €/tCO$_2$ affects the pulpwood price only marginally, while a subsidy for energy has a much stronger effect (Fig. 6). However, in the long term (2030), a very high carbon emission price is going to have a stronger impact on pulpwood prices, but still somewhat lower compared to the subsidies' impact, especially in the short to medium term (2020–2025).

Overall, increasing carbon emission prices up to the high 100 €/tCO$_2$ level has a relatively marginal impact (about 2% reduction in 2030) on the wood-based industry production and a marginal impact on EU harvest (2% increase in 2030). A subsidy of 30 €/MWh to the wood-based energy sector in the four EU member countries will by 2030 have a much more pronounced impact on the European wood-based industry as it gives relative to the low carbon

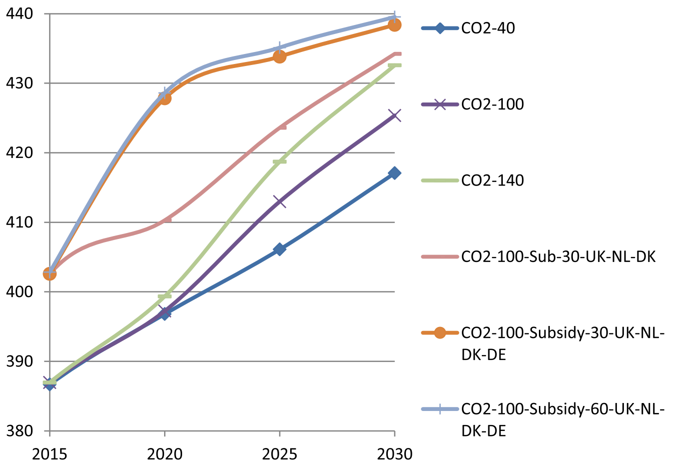

Fig. 4. EU region (with Norway and Switzerland) projected industrial roundwood harvest development, *Y*-axis – harvest, million m^3.

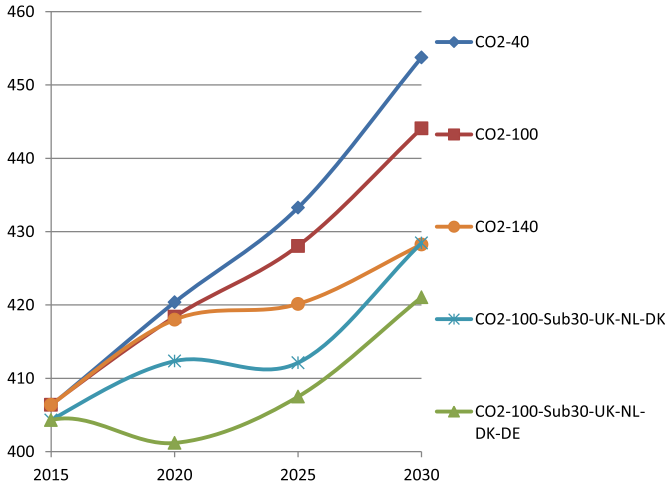

Fig. 5. EU region (with Norway and Switzerland) projected industrial wood use for forest products development, *Y*-axis – wood use, million m^3.

price scenario without subsidy: 8% reduction in the forest industry production, 5% increase in harvest level, about 30% increase in the pulpwood prices, and a nearly four times increase in EU wood imports (see Fig. 7). Additional wood imports are projected mostly from North America, Russia and Latin America mainly in the form of wood pellets and wood chips.

4. Conclusions

Several EU countries also support the use of wood biomass for heat and electricity with other policy instruments than EU ETS, for example feed-in tariffs and various kinds of premium bonuses and subsidies. Here, we studied the impact of subsidies on the production of wood-based electricity and heat under different levels of carbon emission prices. Even a relatively modest subsidy or bonus of 30 €/MWh for electricity generation (3 eurocents/kWh) used in just a few EU member countries leads to a substantial increase in the use of industrial wood use for energy, even under a modest carbon price. These energy wood subsidies can boost the demand for wood for electricity and heat more than increasing carbon emission prices. However, they are not cost-efficient from the point of view of reduction of the carbon emissions in the whole energy sector. Depending on coal, gas and CO_2 prices, increasing the use of wood for energy with subsidies can lead to lower displacement of coal and higher displacement of gas, which produces less CO_2 emissions than coal. It would be more efficient to increase CO_2 prices than to use subsidies for wood-based energy. However, it is unlikely that in the short term (2020) the carbon price will rise to a sufficient level to change coal with gas electricity in favour of gas. The latter depends on the gas prices, but with the current European gas prices it will take the carbon price to rise to 60 €/tCO_2 and more to change the situation in favour of gas. Nevertheless, considering the fact that subsidies for the use of woody biomass for energy are widely used, it seems that these subsidies are likely to be the major driving force behind the increasing use of wood biomass for energy.

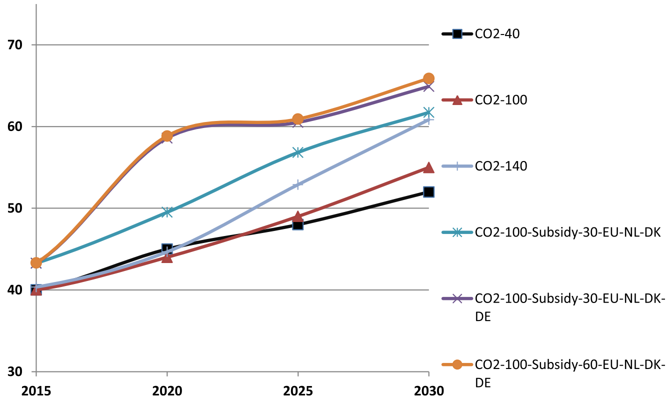

Fig. 6. EU region (with Norway and Switzerland) projected pulpwood price development, *Y*-axis – price, €/m^3.

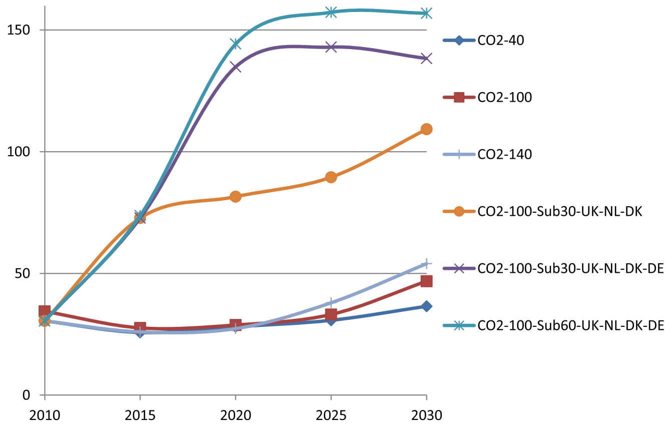

Fig. 7. EU region (with Norway and Switzerland) projected industrial wood imports development, *Y*-axis – imports, million m^3.

The study shows that increased EU imports of wood chips and pellets are going to be a major source for sustaining the growth of wood biomass use for energy. The EFSOS II report points out that it is paradoxical to achieve targets designed to improve energy security and self-sufficiency by increasing imports from overseas [25]. In addition, there is a growing competition for wood fibre on the global markets, especially in Asia. And increasing wood harvests overseas because of growing EU imports may cause indirect land use change, off setting the positive effects of using wood for energy. Thus a growing use of imported energy wood may lead to an increase of carbon emissions embedded into imports. From a consumption perspective, just four countries (Germany, France, Italy and the UK) have CO_2 emissions of one billion tonnes yearly above the production-based system currently used in policy [36].

A rapid move to wind and PV solar power is necessary if emissions are to be constrained. However, wind and solar power still requires huge subsidies to support the rapid growth which has been seen over recent years, and as Italian experience with solar power shows, these subsidies are often used inefficiently, which creates additional problems to be solved in the future [37]. The intermittent nature of wind and solar power requires the running of costly backup capacities, which has to rely on biomass if fossil fuels have to be avoided. Natural gas could be the most suitable fuel for backup capacities in the medium term due to lower carbon emissions, but it will require substantially increased CO_2 emission prices to make gas power more competitive than coal. Subsidies for coal with wood co-firing improve coal power competitiveness. Such subsidies may increase the use of wood for energy substantially in the short term. However, when the subsidies are lifted, the use of wood for coal co-firing may cease to be an economical alternative.

A viable long-term goal to support the development of the new energy conversion technologies is to use sustainable and low-cost wood biomass supply sources, such as forest residues and small trees from thinning. It seems then more beneficial in terms of long-term sustainable growth to support new innovative bioenergy conversion technologies such as biomass torrefaction [38] as just one example, which may provide a cost-efficient way to utilise low-cost forest and agricultural residues. This will allow the use of biomass feedstock that inherently avoids land use change.

From the energy and forest sector point of view the best way to reduce carbon emission is to set a carbon tax (CO_2 emission price) and let the market decide the most cost-efficient allocation. Wood biomass will play an important role regarding renewable energies, but there are a number of risks involved like potential land use and harvest changes outside the EU region as well as potential negative impacts on biodiversity and other environmental factors. Policies aiming at the increasing use of biomass for energy should be carefully evaluated against various risks, and the most risky and controversial one should be avoided. So far based on this study's results, subsidizing coal with wood co-firing seems to be the most controversial policy, unless wood biomass is sourced from forest residues or small trees from thinning, which is not the case with the present wood to energy conversion practices. Our approach, even if simplified, allowed us to endogenize the demand for energy wood and to examine consistently the impacts of policy instruments such as carbon price and subsidies for energy generation on the wood market and on the volume of wood biomass used for heat and power.

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